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ABSTRACT

A study was conducted to refine and coordinate occupational analysis, job performance aids, and elements of the instructional systems development process for task specific Air Force maintenance training. Techniques for task identification and analysis (TI & A) and data gathering techniques for occupational analysis were related. While TI & A and occupational analysis can function as complementary technologies for major improvements in Air Force maintenance, there are substantial incompatibilities between them. TI & A technology identifies specific tasks for specific hardware whereas occupational analysis identifies sets of heterogeneous maintenance tasks across an Air Force Speciality Code (AFSC). Expansion of the latter technology by gathering information on hardware-specific bases is necessary to effectively combine both TI & A and occupational analysis. The gathering of hardware-specific information and the gathering and displaying of data on activities which are common elements of many maintenance tasks such as the use of test equipment and hand tools are proposed. Analysis of this data will identify patterns of personnel/job/hardware relationships for reclustering hardware for improved specialty codes and cost-effective instructional systems development. The identification of such clusters will result in better personnel practices, more cost-effective utilization of Air Force manpower, and improved maintenance. (MN)

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OCCUPATIONAL ANALYSIS TECHNOLOGY: EXPANDED ROLE IN DEVELOPMENT OF COST-EFFECTIVE MAINTENANCE SYSTEMS

By

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November 1980

Final Report

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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The objective of this study was to refine and coordinate occupational analysis, job performance aids (JPAs), and elements of the instructional systems development (ISD) process for task specific maintenance training. More specifically, the purpose was to interrelate techniques for Task Identification and Analysis (TI&A) (from the technologies for JPAs and task-specific ISD) and data gathering techniques for occupational analysis. Occupational analysis and TI&A can function as complementary technologies for major improvements in Air Force maintenance. However, a comparative analysis of TI&A and current occupational analysis technologies indicates substantial incompatibilities between them. The Task Identification Matrix (TIM) of the TI&A technology identifies *specific* tasks for each specific hardware to which it is applied. Such specific tasks are described in terms of maintenance

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FORECAST
technical data presentation
costs of hardware ownership
Behavioral Analyses of Tasks (BAT)
personnel systems for maintenance
Fully Proceduralized Troubleshooting Aids (FPTA)
curriculum development (technical training)
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Item 20 Continued:

functions (such as checkout, align, and troubleshoot) coupled with an appropriate portion of the hardware being considered. In contrast, although using similar maintenance functions, the occupational analysis technology identifies *sets* of heterogeneous maintenance tasks across an Air Force Specialty Code (AFSC) without regard to the specific hardware in the AFSC; this hardware is frequently of varying vintages of design. By neglecting the real differences among tasks within the same set, from hardware to hardware, current occupational analysis results in oversimplified and distorted portrayals of job content of many maintenance AFSCs. More sensitive occupational analysis procedures should be developed and used to gather, to analyze, and to display job data generated. Proposals are made for expanding the capability of the technology by gathering information on hardware-specific bases, which makes possible the reporting of results in terms of hardware-specific *sets* of tasks. This hardware-specific feature permits data to be gathered against important frames of references other than AFSCs, such as by a major weapon system, by groups of weapon systems, by major command, or by maintenance units. The use of hardware managers from the Air Force Systems Command or Air Force Logistics Command, as readily available sources of hardware-specific information, is proposed. Proposals are also made for gathering and displaying data concerning activities which normally are common elements of many maintenance tasks such as the use of test equipment and hand tools. Appropriate analyses of data gathered on these bases will identify important *patterns* of personnel/job/hardware relationships for reclustering of hardware for improved maintenance specialty codes as well as for cost-effective applications of task specific ISD and FPJPA technologies. Once such clusters are identified, their specific task content can be ascertained and analyzed for task-specific ISD and FPJPA development using the TI&A technology. Such reclustering, coupled with the use of FPJPA and task specific ISD, would result in better personnel assignment practices, more cost-effective utilization of Air Force manpower and improved maintenance. These improvements would be further reflected in substantial reductions in the life cycle costs of ownership of hardware systems.

PREFACE

This report represents a portion of the exploratory development program of the Logistics and Technical Training Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio.

The preparation of this report was documented under Task 171004, Job Performance Aids for Air Force Maintenance Technicians. The Task is part of Project 1710, Training and Personnel Factors in System Design, Maintenance and Operations. The effort represented by this report was identified as Work Unit, 17100427. Mr. Robert Johnson was Task Scientist. Dr. Ross L. Morgan was Project Scientist.

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OCCUPATIONAL ANALYSIS TECHNOLOGY: EXPANDED ROLE IN DEVELOPMENT OF COST-EFFECTIVE MAINTENANCE SYSTEMS

I. INTRODUCTION

The human factors technologies that impact personnel and training programs include occupational analysis, instructional systems development (ISD), job performance aids (JPAs), maintenance manpower modeling, and human resources in the design and life cycle costing of systems. Each of these technologies provides benefits far beyond its cost, but independent development and implementation results in some inefficiency. These technologies are approaching the degree of sophistication that will allow further refinements and coordination and will increase their power, precision, and effectiveness.

The objective of the study discussed in this report was to refine and coordinate occupational analysis, JPAs, and elements of the ISD process. More specifically, this report interrelates techniques for Task Identification and Analysis (TI&A) (from the technologies for fully proceduralized job performance aids (FPJPA), and task specific ISD) and data gathering techniques for occupational analysis. An indication is made of ways to extend the techniques and make them more mutually supportive. Through such mutual support they can achieve important operational benefits.

II. TASK IDENTIFICATIONS AND ANALYSIS REFINEMENTS[1] REQUIRED FOR FULLY PROCEDURALIZED JOB PERFORMANCE AIDS AND TASK SPECIFIC TRAINING

Research and development (R&D) on FPJPA and coordinated task specific training for maintenance personnel has produced techniques for describing the human-machine interactions in maintenance. These techniques include elements such as (a) standard maintenance functions and action verbs, (b) a working definition of a maintenance task, (c) a scheme for task identification, and (d) schemes for analyzing identified tasks. These elements are described below.

Standard Functions and Action Verbs

The establishment of standard maintenance functions and action verbs has been one of the widely accepted results of the JPA effort entitled "Presentation of Information for Maintenance and Operation (PIMO)." Early in the PIMO project, it was found that maintenance people used many maintenance action verbs and functions, some with several different meanings. Part of this confusion was caused by the language used in maintenance technical orders, which were written by many different people and produced by many different hardware manufacturers. As a result, maintenance technicians themselves generally did not use precise language.

[1] Much of the early R&D concerning FPJPA and coordinated task specific training for maintenance personnel was an outgrowth of the task analysis work of Miller (1953). These relationships are documented in Foley (1973). Continued R&D on FPJPA and task specific training have resulted in many refinements to the task identification and analysis process.

A study was made to identify and define these action verbs. Where two or more verbs were used to indicate a similar action, one verb was selected for inclusion on a preferred list. The use of the preferred verbs of this list is now a firm requirement of several maintenance manual and technical order specifications of the military services, as well as of the more advanced AFHRL draft specifications (see AFHRL-TR-73-43(I) Joyce, Chenzoff, Mulligan, & Mallory, 1973a, pp. 97-142). These standard maintenance functions and action verbs are used in the production of maintenance directions for new systems such as the A-10, F-5E, and F-16 aircraft. Such verbs are also used in the maintenance directions for operational aircraft such as C-141, B-52, KC-135, and F-106.

Standard Maintenance Functions and a Working Definition of Maintenance Tasks

Within this list of action verbs are a number of key maintenance action verbs or functions such as checkout, adjust, align, calibrate, disassemble, assemble, remove, and install. A list of such functions is also found in AFHRL-TR-73-43(I), pp. 19—20. The distinguishing feature of each such functional verb is that its combination with an appropriate specific hardware unit or component as its predicate object forms a task statement. This combination provides a convenient working definition for a maintenance task.

One of the lessons learned from several FPJPA development efforts is that a complete list of tasks must be obtained for each applicable level of maintenance for each hardware. Each task must be identified so that adequate *provisions* can be made *to insure* its performance. Once a *task* is identified, it should be submitted to several analyses to determine its behavioral content and the most effective means for insuring its efficient accomplishment.

Task Identification Matrix (TIM)

Some version of a Task Identification Matrix (TIM) is the key device for effecting the human-machine interface. The TIM provides the means for identifying all the maintenance tasks which are generated by the hardware and its maintenance concept. The idea of using such a matrix is not new. Versions of the TIM were used in the 1920's and 1930's by vocational educators (Selvidge & Fryklund, 1930). The versions found in AFHRL-TR-71-53(I, II, III) (Folley, Joyce, Mallory, & Thomas, 1971a, 1971b; Joyce, Folley, & Elliott, 1971) and AFHRL-TR-73-43(I, II, III) (Joyce et al, 1973a, 1973b, 1973c) have evolved with the development of the FPJPA. Further use of the TIM probably will result in minor modifications and adaptations. For good communication among all interested users, standardization of format and notation is extremely desirable. As yet, such standardization has not been obtained, but, there are some basic characteristics of all current versions of the TIM.

In current TIMs the left-hand column contains all of the system hardware units and component parts for the level of maintenance for which the maintenance technician has responsibility. Each line item is given a number. The headings for other columns are listed the appropriate maintenance functions, such as adjust, align, calibrate, checkout, handle, inspect, install, operate, remove, repair, service, and troubleshoot.

For each cell in the matrix, an entry such as one of the following is required.

O - No maintenance task of this type is performed on this end item at the level of maintenance being considered.

T - Maintenance tasks of this type are performed on this end item. Indicate more than one task in a cell by a subscript that shows the number of tasks.

E_T - The activity at this end item level is an element of a higher level task.

Thus, the TIM is a device that systematically exposes each appropriate functional unit and/or component of a hardware to all maintenance functional verbs. *If properly executed* it identifies all the maintenance tasks which that hardware can demand of its maintenance technicians. Also, it limits the scope of each hardware specific task which is identified. As the result of the maintenance concept for each hardware, the TIM or TIMs will identify a different mix of maintenance tasks for each level of maintenance (organizational, intermediate or depot). Although all three levels of maintenance can be included on one TIM, for complex hardware it usually is advisable to develop a separate TIM for each level. (Since depot maintenance usually is performed by experienced civilian rather than military personnel, it has not been considered in AFHRL TR-73-43(I)).

The Analyses of Identified Tasks

Two separate and distinct levels of analysis of maintenance jobs are emphasized: task identification and analyses of identified tasks. So far in this report only, task identification and/or job analysis have been discussed . Task identification is often confused with task analysis. Each analysis of identified tasks must reflect the purpose of the analysis. Some analyses are for (a) design tradeoffs between technician and machine, (b) job simplification, (c) measurement of job performance, (d) content of job instructions, (e) training for task performance, (f) determination of critical tasks, and (g) preparation of job descriptions.

A prime objective of the analyses required for each task for the development of FPJPA is to identify all the *task steps* or directions required to perform that task and to ascertain the necessary work and pictorial content for each direction. This requires that each direction contain all of the *cues* required by members of the target population to perform the task step which is represented by that direction. Directions and guidance for performing most of the analyses required to meet these objectives are found in AFHRL-TR-73-43(I, II, III) (Joyce et al., 1973a, 1973b, 1973c). Additional guidance concerning necessary cues is found in AFHRL-TR-75-38 (Shriver, 1975).

Task Identification and Analysis: A Hardware Specific Task Analysis Technology

The TI&A technology is primarily a hardware specific technology and when properly applied does an excellent job of identifying all the maintenance tasks demanded by a specific hardware. However, the TI&A technology has its limitations primarily in the area of providing job information across hardware quickly and at a reasonable cost. As will be discussed later, a large amount of such across hardware information is required to identify specific hardware or clusters of hardware for which the most cost effective utilization of maintenance personnel can be made, including cost implementation of the FPJPA and task-specific ISD technologies.

A great deal can be learned from comparing the outputs of TI&A across several systems once such outputs are available for all hardware under consideration. However, because of time and money limitations, the best that one can expect is that TI&A will be performed for all new hardware and for that in-place hardware retrofitted with FPJPAs. Even if TI&A outputs were available for all hardware to indicate the specific tasks which should be performed, these outputs would not provide information as to where clusters of personnel and hardware are located. Neither would the outputs indicate whether the personnel are performing the job activities TI&A technology indicates they should be performing.

III. A COMPARISION OF OCCUPATIONAL ANALYSIS TECHNOLOGY AND HARDWARE ORIENTED TASK IDENTIFICATION AND ANALYSIS TECHNOLOGY

Currently the occupational analysis technology is the most powerful, *in place* tool available to the Air Force and other DOD agencies for ascertaining what people *do*. This technology can gather Air Force-wide job information, in a rather short time, at a reasonable cost. The potential power of occupational analysis for improving maintenance has not been exploited fully. The technology has been developed to operate within the framework and constraints of current maintenance Air Force Specialty Codes (AFSCs) of the Air Force personnel assignment system. As a result of this and other factors, the power of the technology to identify and quantify human/machine interface matches and mismatches has been extremely limited. Several of these factors are considered in this section to support a number of proposed changes for increasing the power of the technology to better represent the complexities of the world of maintenance.

Standard Action Verbs and Functions

The use of non-standard maintenance action verbs and functions has long been a confounding factor in attempts to describe and work with maintenance activities. Fortunately, this problem may eventually disappear. For several years, it has been firm Air Force policy that all new developments of maintenance directions contain the standard maintenance functions and action verbs discussed earlier. As discussed earlier, such verbs are in use on several in-place Air Force systems and are being used on all new Air Force systems. It will be several years, of course, before all maintenance manuals reflect such language.

The use of these standard functional verbs in the "task/duty" statements of the occupational analysis technology is a necessary but not sufficient step for increasing the useablility of this technology. Their use would increase the compatibility of the outputs of occupational analyses with the outputs of hardware specific TI&A and with the language of modern maintenance directions.

Specific Maintenance Tasks and Sets of Maintenance Tasks

The occupational analysis technology when applied to maintenance jobs usually deals with sets of tasks across an AFSC rather than with specific hardware tasks. Further, each set is treated as though all of its tasks had a high degree of homogeneity and discreteness. This tacit assumption of homogeneity probably was valid 15 or more years ago when the number of hardware items assigned to an AFSC was usually small and when all such hardware generated very similar maintenance tasks. For a number of reasons, such an assumption is no longer appropriate, and as will be discussed later, assumption of discreteness has never been appropriate for most sets of maintenance tasks.

Heterogeneity

In many cases, the variance in content and difficulty is extremely great among specific tasks of a set represented by a "duty/task" statement. Because of the number of vintages of hardware design, the application of the same functional verb to a cluster of hardware having the same operational function often produces a task/duty statement that represents a set of very heterogeneous specific tasks. For example, personnel with AFSC 328X4, Avionics Inertial and Radar Navigation Specialist, are maintaining 60 or more major electronic subsystems. Many vintages of hardware design are represented. The checkout activity for each is different. The lack of correspondence of alignment, calibration, and troubleshooting tasks from one specific equipment to another is even greater.

An example of the lack of correspondence from one hardware to another is the wide difference in the content and difficulty of troubleshooting tasks between two doppler radars. The AN/APN-174, which is used on the C-130 and C-141, has approximately 14,000 shop replaceable units (SRUs), whereas the IDNE on the C-5 has only 28. As a result, "task/duty" statements such as "Troubleshoot Doppler Radars" should not be treated as a set of homogeneous tasks.

Interactions and Overlaps of Hardware Specific Tasks

There are a number of other factors which contribute to the low degree of discreteness among maintenance tasks and sets of maintenance tasks. One confounding factor concerns the interaction among maintenance tasks for one hardware. A four level hierarchy of dependencies can be stated. Figure 1 gives a graphic presentation of these dependencies among sets of maintenance tasks and activities.

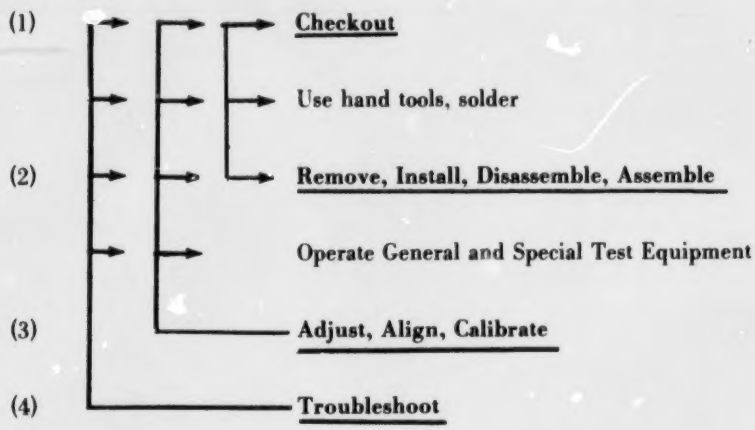

Figure 1. **Dependencies among maintenance functions for an electronic hardware (functions underlined).**

The checkout of the AN/APN-147 (Doppler Radar), for example, can be a specific task in its own right, But the same checkout activity becomes an element of other tasks (such as the set of calibration tasks) for the AN/APN-147. The calibration of Doppler radar includes the operation of specific hand tools, as well as the checkout activity. Troubleshooting can include all of the other activities. Any troubleshooting task should begin and end with an equipment checkout. Efficient troubleshooting practice usually requires the use of a cognitive strategy to track the dependent activities. Troubleshooting of an electronic equipment such as AN/APN-147 requires the use of general and special test equipment. It may require remove and install activities and/or adjust, align, and calibrate activities.

Because of these various dependency relationships, each statement (representing a specific task or set of tasks) generated by coupling functional action verbs (such as checkout, remove, install, disassemble, adjust, align, calibrate, or troubleshoot) with a specific hardware or with appropriate components of a specific hardware cannot be considered as discrete. The same also applies to similar statements representing sets of tasks covering clusters of hardware.

A *second* confounding factor concerns statements representing sets of tasks which have been generated by the same functional verb applied to different levels of maintenance. The mixes of tasks in *sets* representing the same maintenance function such as troubleshooting can be quite different for organizational, intermediate and depot levels of maintenance for the same hardware. In addition, due to different output standards, the procedures used for alignment or calibration tasks may be quite different for these levels of maintenance for the same hardware. And the proportions of tasks assigned to each level vary greatly from hardware to hardware.

In the Air Force, most organizational and intermediate maintenance is performed by enlisted maintenance personnel. Maintenance personnel assignment codes seldom differentiate between the two levels of maintenance. So an indication that an airman "performs troubleshooting on the AN/APN-147," does not distinguish between relatively simple organizational level troubleshooting and highly complex intermediate troubleshooting or both. In this regard, the maintenance assignment codes used by the Army and Navy usually differentiate between levels of maintenance.

A *third* confounding factor impacting the discreteness of statements representing tasks and sets of tasks concerns various modes of maintenance such as preventive and corrective maintenance (sometimes called scheduled and unscheduled). Each of the two statements "performs corrective maintenance on the Doppler Radar AN/APN-147" and "performs preventive maintenance on the Doppler Radar AN/APN-147" represents a rather heterogeneous set of tasks. Both of these sets would also include the task "performs checkout procedure for the AN/APN-147," As well as the subset of tasks "performs AN/APN-147 alignments." So "performs preventive maintenance on the Doppler Radar AN/APN-147" should not be treated as a discrete statement to be compared with the statements "performs checkout procedure for the AN/APN-147," and "performs AN/APN-147 alignments."

Impact on Occupational Analyses for Maintenance Specialties

The current occupational analysis technology is not sufficiently sensitive to these several significant factors, some of which are generated by the many hardware systems of varying vintages of design now in the Air Force inventory. Other of these factors result from the interactions and overlaps of tasks for each specific hardware. Consequently, the application of this technology to many AFSCs results in oversimplified and distorted portrayals of their task content. In fact, a major factor producing complexities is the mix and quantity of hardware in many AFSCs, a factor which is not adequately considered by the current occupational analysis technology. So more sensitive procedures should be developed and used to gather, to analyze, and to display job data. Further the use of these procedures should not be limited to the current AFSC structure.

IV. A PROPOSED EXPANSION OF OCCUPATIONAL ANALYSIS FOR THE SUPPORT OF A MORE EFFECTIVE, HARDWARE RELEVANT MAINTENANCE PERSONNEL SYSTEM

Most of the factors causing the current human-machine interface complexities are already in place and cannot be eliminated or reduced. In the future, a few factors can be reduced somewhat by more careful and serious consideration of human factors tradeoffs for maintenance during the conceptual and design phases of hardware. However, the Air Force and other DOD agencies have large investments in hardware of many diverse designs and maintenance concepts. Such designs and concepts are largely responsible for the heterogeneous mixes of maintenance tasks now existing in maintenance specialties. These complexities contribute greatly to the current high life cycle costs of ownership of hardware systems, but tools are available for reducing the effects of such complexities.

Properly designed and developed task instructions (which contain the necessary cues for first-term maintainers) provide a now proven technology for reducing the effects of maintenance complexities. FPJPA technology can reduce the effects of differences in content and difficulty among tasks in any hardware-specific set of tasks. Usually most of these differences can be accommodated by maintenance instructions of the FPJPA variety. This technology can also accommodate many of the differences among hardware of diverse design and functions.

FPJPAs could be developed for all of the maintenance tasks to be found in a highly heterogeneous cluster of hardware such as found in AFSC 328X4, Avionics Inertial and Radar Navigation Specialist but would not be the most cost-effective approach for several reasons, including the fact that the hardware and personnel for this AFSC are scattered throughout the Air Force. Initially, smaller clusters of hardware types should be identified which are less physically scattered and which require rather large groups of maintainers.

The power of the FPJPA technology permits the *reclustering* of hardware for first-term assignment codes on bases other than the operational function of hardware, such as by weapon system, by groups of weapon systems, and by groups of maintenance units. The assignment of maintenance personnel to such hardware clusters would result in more efficient on-the-job utilization of personnel. An individual could be expected to work across several hardware of differing functions as the day-to-day workload shifted. But such cost-effective applications require the identification of large groups of personnel who are assigned to manageable clusters of hardware.

Since the maintenance instructions could carry most of the task content, the time now devoted to entry training could be greatly reduced for each cluster of hardware for which compatible FPJPAs are available. The content of both the FPJPAs and accompanying training would have to be carefully controlled by the TI&A technology. When comparable FPJPAs are available for all the hardware in a cluster, initial training for first-enlistment personnel would be a rather short task specific program. This program would consist of supervised practice on the use of hand tools and test equipment together with practice on the use of FPJPAs for one type of hardware in the cluster. The graduate could then be expected to perform maintenance tasks on other hardware in the cluster with a minimum of introductory training. A more complete treatment of the combined powers of TI&A, FPJPA, and task specific ISD technologies is found in technical reports AFHRL-TR-78-24 (Foley, 1978a) and AFHRL-TR-78-25 (Foley, 1978b). In fact, this training/FPJPA tradeoff adds a new dimension to ISD, and such a development would more accurately be called a task specific systems approach to training and aiding development.[2]

The combination of task specific ISD and FPJPA (for all maintenance tasks for an entire cluster of hardware) provides great operational flexibility as well as great savings in training. Such combined applications of FPJPA/task specific ISD also would permit a gradual modification of the personnel system for maintenance. Basically, an AFSC would be generated for each cluster of hardware. This requires a mechanism for identifying the hardware which should be placed in the new clusters.

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[2]These reports also consider the relative effects of other types of improved maintenance guidance and information (IMG&I), none of which are quite as effective for reducing the effects of human-machine interface complexities. Many current IMG&I efforts have been applied to only the organizational level of maintenance. Most of these efforts utilize some sort of FPJPAs for non-troubleshooting (non-TS) tasks, but for troubleshooting (TS) tasks, less effective IMG&I, such as enriched FORECAST aids or Logic Tree Troubleshooting Aids (LTTAs), are utilized. The Army program entitled, Skill Performance Aids (SPAs), formerly entitled "Integrated Technical Documentation and Training" (ITDT), utilizes such mixtures. (The former title is more indicative of the objective of this Army program.)

In summary, it is now very difficult if not impossible to determine the quality and location of specific hardware systems and subsystems coupled with the numbers and types of people who are performing the various maintenance tasks or sets of tasks for each hardware. But such information is required to accomplish cost-effective reclustering of hardware with appropriate personnel. Such human-machine interface information is required not only by AFSC, but also by weapon systems, by commands, and by maintenance units within commands. The recommended modifications and expansions in scope of occupational analysis technology which follow should provide the capability for gathering the necessary human-machine interface information, as well as retaining the capability for gathering information for traditional occupational analyses.

Proposed Survey Procedures for Gathering Human-Machine Maintenance Interface Information

Figure 2 is a proposed format for obtaining hardware specific, human-machine interface information concerning maintenance. It is envisioned that each maintainer will complete such a form for each hardware system maintained. The order in which these forms are completed would reflect the relative amount of interaction that the maintainer has had with each hardware. This procedure should not require an extensive expansion in size when compared to current surveys. Most first-enlistment airmen work on very few of the hardware assigned to an AFSC, many times on only one. In most cases, the number of hardware supervised by 7 skill-level technicians should not be excessive since any one maintenance supervisor seldom has more than five or six hardware items. The use of such a format has several important characteristics and advantages.

1. On Figure 2 the maintenance functions which appear in the center column are taken from the standard list of maintenance functions now specified for Air Force "Job Guide Manuals" (see AFHRL-TR-73-43(I), Joyce et al., 1973, pp. 19-20). The nine headings for the left-hand columns represent several interactions which an individual may have had with each maintenance function and the specific hardware under consideration.[3] A check in any cell formed by columns 2, 3, or 4 and a row representing a function such as adjust will usually identify a hardware specific *set* of tasks represented by a statement such as "Adjusts the AN/APN-147." A check in a cell in column 2 or 3 indicates that the individual either has performed or assisted in the performance of at least some of the tasks within the identified set; a check in a cell of column 1 indicates the individual has received "hands on" training on such tasks; a check in a cell of column 4 indicates that the individual has supervised others in the performance of such tasks; and a check in a cell of column 5 indicates that the individual has trained others in such tasks. For most first enlistment personnel, cells of columns 2 and 3 are most important.

2. Columns 6 through 9 were included to further define and limit the scope of each set of tasks identified by checks placed in one or more of cells within the first five columns. The feature provided by columns 6 and 7 requires maintainers to indicate whether they have performed sets of tasks with the same function at the organizational (O) (flight line) or intermediate (I) (field shop) levels of maintenance or both. For example, checks in the cells of column 3 and 6 of the "adjust" row would indicate that the individual has performed tasks in a set of tasks represented by the statement "Performs *organizational level* adjustments of the AN/APN-147." In a few cases, a check in such cells may identify a specific task, such as "performs organizational level checkout of the AN/APN-147," which is a task in its own right. This information is extremely important since the task mixes for sets of tasks with the same function can be quite different in content at each level of maintenance. The relative difficulty of such sets also can be quite different.

[3] The idea for columns 1 through 5 was obtained from CDR Bruce Cormack of Ottawa, Canada.

I. The information requested on this page concerns the specific major hardware system or subsystem on which you have performed the most maintenance.

A. General Information

1. What is the nomenclature or designator of this hardware?_____ (Example: AN/APN-147)
2. If applicable, on which aircraft is this hardware installed? _____
3. To what command are you assigned? _____
4. To what maintenance unit or squadron are you assigned? _____

B. Directions for Left Columns

1 In columns 1 thru t check the appropriate column(s) which best describe your experience with each maintenance action.

2. In columns 6 and 7 indicate if such expeience was at organizational or intermediate level of maintenance or both.

3. In columns 8 and 9 indicate if such experience was in the scheduled (preventive) or unschedule (corrective) mode of maintenance or in both.

C. Directions for Right Columns

Same as for current Surveys (To be checked for only activities which you have checked that you have performed or assisted in the performance — columns 2 and 3 of Left Columns)

Column Heading (Left)

1 Received "hands on" training on activity
2 Assist in performance of activity
3 Perform activity
4 Supervise performance of activity
5 Train others on performance of activity
6 Organizational level (flight line)
7 Intermediate level (field shop)
8 Scheduled maintenance (preventive)
9 Unscheduled maintenance (corrective)

Column Headings (Right)

1 Very small amount
2 Much below average
3 Below average
4 Slightly below average
5 Above average
6 Slight above average
7 Above average
8 Much above average
9 Very large amount

1 2 3 4 5 6 7 8 9	Maintenance Actions (Functions)	1 2 3 4 5 6 7 8 9
	Checkout	
	Adjust	
	Align	
	Calibrate	
	TS[1] to LRU[2]	
	TS to SRU[3]	
	TS Cables and Plugs	
	Remove	
	Install	
	Disassemble	
	Assemble	

1 TS — Troubleshoot 2 LRU — Line Replaceable Unit 3 SRU — Shop Replaceable Unit

Figure 2. **Proposed survey format for obtaining hardware specific maintenance job data.**

3. The use of the standard functions (center column) would make the language of "task-duty" statements (sets of maintenance tasks) appearing in occupational analysis readouts compatible with the language used in the products of TI&A, as well as with the language used in modern maintenance instructions. For example, a set of tasks identified by the use of Figure 2 could be "performs alignments in the AN/APN-147 at the intermediate level of maintenance." The TIM from the TI&A technology can be used to help identify all of the alignment tasks in this set of tasks. In addition, if the maintenance manual were complete, directions for each task in the set could be identified in the maintenance manual, but many traditional manuals are not complete in this regard.

4. Since the data generated by the completion of Figure 2 are hardware oriented rather than AFSC oriented, it is possible to gather data against, not only AFSCs, but other important frames of reference. For example, maintenance data can be gathered by a major weapon system, by groups of weapon systems, by major command, or by maintenance units.

5. The nine right hand columns correspond to the columns currently used in occupational analysis surveys. It is envisioned that the cells generated by these columns will be used only when an individual indicates having performed or assisted in the performance of a set of maintenance tasks. Because many maintenance task/duty statements used in surveys (as well as tasks identified by TIMs) are not discrete, current procedures used for manipulation of survey data are not suitable for maintenance. However, if manipulated differently, such an estimate of the time devoted to sets of tasks probably will be an important consideration for reclustering of hardware.

Some Proposed Matrices for Displaying Human/Machine Interface Relationships

As indicated previously, the surveys proposed in Figure 2 would provide the capability for collecting hardware specific data within the constraints of current maintenance AFSCs as well as outside these constraints, such as by a weapon system, a group of functionally related weapon systems, or maintenance units within a command. Table 1 provides descriptions for proposed sets of matrices which could be generated from data obtained from these various areas of inquiry. When generated, such matrices would, of course, help identify patterns of hardware/personnel combinations for the reclustering of hardware for cost-effective applications of the FPJPA, other IMG&I, and/or task specific ISD technologies. But matrices of this type also would provide valuable bases for restructuring existing AFSCs.[4]

For example, some AFSCs or parts of AFSCs might be split profitably for organizational and intermediate levels of maintenance. In some cases, AFSCs probably should be split between troubleshooting and non-troubleshooting tasks. It certainly is not cost effective to train large numbers of people as if they are going to perform both organizational and intermediate levels of maintenance when substantial numbers perform tasks at only one level. Likewise, for either level, it is not cost effective to train all personnel in an AFSC as if they are going to perform both non-troubleshooting and troubleshooting tasks when only a few actually perform troubleshooting tasks. As indicated previously, some current trends in technical order development for new weapon systems would support such splits.

[4]Whether or not the FPJPA and coordinated task specific training technologies are applied to the solution of current maintenance and maintenance personnel problems, there is an urgent requirement for the graphic information described in Figure 1. Without such information the extent and magnitude of the mismatches between the maintenance tasks (generated by current hardware) and the current maintenance personnel system cannot be identified in a meaningful fashion. These mismatches must be identified before they can be corrected.

Table 1. **Descriptive Summaries of Proposed Matrices for Displaying Human-Machine Interface Relationships**

Proposed Matrices	Description of Line Items	Description of Column Items	Description of Cells	Proposed Order of Line Items	Remarks
Set of matrices concerning the number of maintenance personnel performing the various sets of tasks by maintenance function and by specific hardware for one AFSC.	Hardware nomenclatures as identified by survey (Figure 2).	Maintenance functions or functional action verbs (such as checkout, align, troubleshoot) plus a "Total" column.	Number of personnel indicating performance of set of tasks represented by each cell.	Rank order by cells in the "Total" column, by command plus rank order by "Total" column alone. ("Totals" for ranking purposes only).	1. Set should include at least six matrices: two each for 3, 5, and 7 skill levels; one, for the organizational level of maintenance, and the other for the intermediate level.
Set of matrices concerning the number of maintenance personnel performing the various sets of tasks by maintenance function and by specific hardware for several AFSCs.	Same as above.	Same as above.	Same as above.	Same as above.	1. Same as above.
Set of matrices concerning the number of maintenance personnel performing the various sets of tasks by maintenance function and by specific hardware for a major weapon system across AFSCs.	Same as above.	Same as above.	Same as above.	Same as above.	1. Same as above. 2. Envisioned that most major weapon systems would be assigned to a limited number of commands, in some cases to only one (such as the C-141 in MAC).
Set of matrices concerning the number of maintenance personnel performing the various sets of tasks by maintenance function and by specific hardware for a group of functionally related weapon systems across AFSCs.	Same as above.	Same as above.	Same as above.	Same as above.	1. Same as above. 2. Envisioned that most major weapon systems would also be assigned to a limited number of commands (such as the C-141, C-5, and C-130).
Set of matrices concerning the number of maintenance personnel performing the various sets of tasks by maintenance function and by specific hardware for maintenance units within a command across AFSCs.	Same as above.	Same as above.	Same as above.	Rank order by "Total" column, by maintenance unit plus rank order by "Total" column alone.	1. Same as above.

Of course, several other displays would have to be developed to handle the training and supervisory data generated by the proposed surveys format.

Appropriate Roles for the Occupational Analysis and TI&A Technologies

Appropriate roles for the proposed occupational analysis technology and the TI&A technology are indicated clearly by a comparison of their capabilities.

The occupational analysis technology as envisioned in this report will be able to gather a large amount of hardware specific human factors information across many hardware. For each hardware it will identify sets of maintenance tasks rather than specific tasks.

The TI&A technology normally is applied to only one hardware at a time and its TIM identifies all of specific maintenance tasks for that hardware. Thus, TIM can be used to identify all of the tasks in any hardware specific set of tasks identified by the proposed occupational analysis surveys.

TI&A procedures together with their resulting products possess the capabilities for prescribing the detailed content of each task for FPJPA and/or task specific ISD, capabilities which the current occupational analysis technology does not have.

Thus, the appropriate prime role for occupational analysis technology will be to gather hardware specific data across hardware on several bases such as by a major weapon system, by groups of weapon systems, by major command, by maintenance units as well as by AFSC, and to analyze such data appropriately. Such analyses would identify patterns of personnel/jobs/hardware relationships for reclustering of hardware and/or personnel for purposes such as cost effective applications of task specific ISD and/or FPJPA technologies.

Once such a cluster is identified, the TI&A technology would be applied to all hardware in the cluster to identify the maintenance tasks in the cluster and determine the detailed content of the task-specific ISD and/or FPJPA required for achieving cost-effective maintenance. Such reclustering coupled with the use of FPJPA and task specific ISD also would result in better personnel assignment practices and more cost-effective utilization of Air Force manpower. All of these improvements would be further reflected in substantial reductions in the life cycle costs of ownership of hardware systems.

The Display of Frequency and Difficulty Data

The proposed surveys form in Figure 2 provides for the collection of frequency data concerning identified sets of tasks. This is the same type of data obtained concerning duty/task items in current occupational analysis surveys. Table 2 describes matrices for displaying these frequency results for each set of tasks identified by the proposed surveys. No attempt is made to manipulate these data as though each set represents a discrete portion of a maintenance job.

As to the rank order for the line items, it should be noted that for each frequency matrix developed in keeping with Table 2, there will be a companion matrix developed in keeping with Table 1 reflecting the number of personnel performing each set of tasks. Comparisons of the two types of data would be facilitated by the same rank order of hardware line items for both matrices.

Table 2 also suggests sets of matrices concerning difficulty of task sets. It is envisioned that a difficulty questionnaire reflecting the same sets of tasks identified by the proposed questionnaire in Figure 2 would be developed and used to collect such data.

Table 2. **Descriptive Summaries of Proposed Matrices for Displaying Frequency and Difficulty Data**

Proposed Matrices	Description of Line Items	Description of Column Items	Description of Cells	Proposed Order of Line Items	Remarks
Set of matrices concerning the adjective level of frequency of performance for each of the various *sets* of tasks by maintenance function and by specific hardware for one AFSC.	Hardware nomenclatures as identified by survey (Figure 2).	Maintenance functions or functional action verbs (such as checkout, align, troubleshoot) plus a "Total" column.	Composite number from 1 through 9 representing the adjective statements of the survey form for the set of tasks represented by each cell-number being the mean or median of the frequency data obtained for each set of tasks.	Same rank order as its companion set described in Table 1.	1. Set should include at least six matrices: two each for 3, 5, and 7 skill levels; one, for the organizational level of maintenance, and the other for the intermediate level. 2. Similiar sets of matrices should be developed when surveys are addressed to population groups other than for single AFSC, such as for several AFSCs, for a major weapon system across AFSCs, for a group of major weapon systems across AFSCs, and for maintenance units within a command across AFSCs.
Set of matrices concerning the adjective level of difficulty of performance for each of the various *sets* of tasks by maintenance function and by specific hardware for one AFSC.	Same as above.	Same as above.	Composite number from 1 through 9 representing the adjective statements of the survey form for the set of tasks represented by each cell-number being the mean or median of the difficulty data obtained for each set of tasks.	Optional.	1. Same as above. 2. Same as above.

The Hardware Manager — An Untapped Source of Information

Each major hardware or hardware subsystem in the Air Force inventory has a manager in either the Air Force Systems Command or the Air Force Logistics Command. This manager has a great deal of valuable information concerning specific hardware, which should support and supplement the data gathered by proposed occupational analysis survey procedures. Such surveys procedures will identify manageable clusters of hardware as well as where each type of hardware in the cluster is located and the number of persons performing various maintenance functions on each hardware at each location.

The hardware manager usually can furnish data concerning the total number of hardware units currently in the Air Force inventory, the number of additional units the Air Force expects to procure, and the location or proposed location of each of these units. The manager also has data concerning the current numbers of LRUs and SRUs in each hardware. These are valuable data concerning the magnitude of troubleshooting tasks the hardware can generate. The hardware manager usually can provide valuable insights regarding significant maintenance problems which are being experienced with the hardware and knows which maintenance units are having special difficulties.

It is proposed that the expanded occupational analysis technology include appropriate mechanisms for systematically gathering such important data as well as for integrating these data with hardware-specific survey data. Such a combination certainly would provide an improved data base for developing cost-effective maintenance personnel and training systems.

V. CONSIDERATION OF THE COMMON ASPECTS OF MAINTENANCE TASKS

The main thrust of this report concerns the divergent characteristics of maintenance tasks and proposals for the occupational analysis and TI&A technologies for identifying and displaying important differences among hardware specific maintenance tasks. There are some threads of commonality that can affect the performance of many maintenance tasks across many hardware. These threads require identification and strengthening.

An examination of Figure 1 indicates two groups of activities which are not underlined. These are maintenance activities which are never tasks in their own right. But they can be extremely important elements of other tasks. They include use of hand tools, soldering, and operating general and special test equipment. With the exception of special test equipment operation, these should be somewhat common activities which are not confined to one hardware.

Common Test Equipment

General test equipment for electonic hardware provides an excellent example of common activities and includes such items as general purpose signal generators, support equipment, oscilloscopes, and voltohm meters (VOM), including vacuum tube voltmeters (VTVM). In addition, a great many electronic hardware items have their own special test equipment requirements.

There is an official Table of Allowances which indicates which test equipment is authorized for each hardware item. Usually, supply personnel will not issue the newer prime test equipment until the older "suitable substitute" equipment is beyond repair. However, operating such a substitute may be quite different from operating the prime authorized test equipment. Also, the accuracy and form of information displays of the substitutes may not match those of the prime authorized equipment. As a result, such display information may not be compatible with the "within-tolerance indications" found in the

maintenance manual — whether the manual be of the traditional type or one of the improved types. A few highly trained and experienced technicians may be able to tolerate such mismatches of information, but such mismatches can modify maintenance tasks so greatly that both training and aiding programs become ineffective for first enlistment-personnel.

Currently, there is no mechanism for determining the extent and locations of such practices but each such practice should be corrected when it is found to exist. By providing such data, the occupational analysis process would provide a needed and valuable service toward the improvement of maintenance.

Soldering

Prior to the introduction of printed circuit boards, soldering of electrical joints could be accomplished with an appropriate iron or gun. This was a common maintenance task requiring special skill which were not mastered by many electronic maintenance personnel.

The combination of printed circuits and extremely small and delicate solid state devices has made the use of the soldering iron or gun inappropriate. As a result, special soldering equipment, called bench top repair centers (BTRCs), such as PRC-150A and PCR-350C, have been developed and authorized for printed circuit work.

Their use also would improve soldering done on older vintage equipment. However, many technicians still are attempting to perform removal and installation on delicate circuit boards, using the inappropriate irons or guns.

For some reason, some shops do not have the approved BTRC. The inappropriate use of soldering irons and guns causes expensive, irrepairable damage. The BTRCs require special manual skills that can be mastered by most people only with hands-on practice.

Proposed Format for Obtaining Test Equipment and Soldering Data

Figure 3 is a suggested format for obtaining test equipment and soldering information. An example of the important information would be a comparison of the authorized test equipment with the actual test equipment for each hardware considered in an occupational analysis survey. The list of authorized test equipment for each hardware from the available official Table of Allowances could be stored permanently in a computer bank for such comparisons. This bank could be given a periodic update by the Air Force Logistics Command agency responsible for its publication.

Such comparative information could be displayed for the Air Force as a whole or by command, base, or maintenance unit.

Successful applications of FPJPA, as well as of task specific ISD technologies, require the use of prime authorized test equipment and soldering equipment. These technologies will not tolerate many so-called "suitable substitutes."

Common Administrative Activities

There are a number of forms, tags, and reporting procedures that are common to all maintenance AFSCs. They are actions that must be performed, But, from the point of view of this report, such actions are rather secondary elements to most maintenance tasks. It is suggested that a standard list of such actions

II. The information requested on this page concerns the test equipment and soldering tools you have used with the major hardware system or sub-system on which you have performed the most maintenance.

A. General Information

1. What is the nomenclature or designator of this hardware?_____(Example: AN/APN-147)

B. Directions

Place a check in the appropriate column to indicate the maintenance activity or activities for which you used each indicated test equipments. If you use test equipment other than those listed, fill in nomenclature in the extra spaces provided and indicate maintenance activity for which each was used.

Column Headings:

Maintenance Activities

1 Checkout
2 Adjust
3 Align
4 Calibrate
5 Troubleshoot to LRU
6 Troubleshoot to SRU
7 Troubleshoot Cables and Plugs
8 Remove and/or install
9 Disassemble and/or assemble

	General Test Equipment:	1	2	3	4	5	6	7	8	9
Oscilloscopes	Tektronix 545B									
	Lavois (equivalent)									
	Hickock (equivalent)									
(Other):										
Meters	Simpson 260 VOM									
	HP-410B VTVM									
	Fluke 803 Differential Voltmeter									
	5245L Electronic Counter									
(Other):										
Signal Generators	URM-25D Signal Generator									
	200CD Wide Range Oscillator									
	Kay Model 860 Sweep Generator									
	SG-299 Signal Generator									
(Other):										
	TS-148 Radar Test Set									
Testers	TS-1100/U Transistor Testor									
	TV-2A/U Tube Tester									

List Special Test Equipment

List Support Equipment

Soldering (Bench Top Repair Centers):
PRC-150A
PRC-350C

Figure 3. **Proposed survey format for obtaining test equipment and soldering data.**

be included as part of any occupational analysis survey for maintenance personnel. It is recommended that the resulting data be treated and reported separately from the data obtained concerning the hardware/human aspects of maintenance jobs.

VI. SUMMARY AND CONCLUSIONS

1. Several human factors technologies impact personnel and training. Occupational Analysis is one, and for purposes of the present report, others are instructional systems development (ISD) and job performance aids (JPAs). This report describes ways to refine and coordinate these technologies. Such refinements and coordination will result in increasing the power, precision, and effectiveness of those technologies.

2. Research and development (R&D) on Fully Proceduralized Job Performance Aids (FPJPA) and task specific training has produced techniques for describing human-machine interaction in maintenance. These techniques include elements such as (a) standard maintenance functions and action verbs, (b) a working definition of a maintenance task, (c) a scheme for task identification, and (d) schemes for analyzing identified tasks.

a. The establishment of a list of standard maintenance functions and action verbs has been one of the widely accepted results of R&D on JPAs. The use of the preferred verbs of this list is now a firm requirement of most maintenance manual and technical order specifications of the military services.

b. Within this list of action verbs are a number of key maintenance action verbs or functions such as checkout, adjust, align, calibrate, disassemble, assemble, remove, and replace. The distinguishing feature of each such functional verb is that its combination with an appropriate specific hardware unit or component as its object predicate forms a task statement. This combination provides a convenient working definition for a maintenance task. Such task statements must be identified for each applicable level of maintenance (organizational, intermediate, or depot). Each task must be identified so that adequate provisions can be made to insure its performance.

c. A Task Identifying Matrix (TIM) is the key device for describing the human-machine interface. It provides the means for identifying all the maintenance tasks generated by the existence of a hardware item, together with its maintenance concept. There are three basic parts to a TIM. *On the left-hand column*, are placed the all system hardware units and components parts to the level for which the maintainer has responsibility. Each of the resulting line items is given a number. *As headings for other columns*, are listed the appropriate maintenance functions, such as adjust, align, assemble, calibrate, checkout, disassemble, install, operate, remove, and troubleshoot. For each cell in the resulting matrix, entries *such as* the following are used: O when no task within the function is performed on the end item under consideration, T when a task is required, and E_+ when the activity is an element of a higher level task.

d. Thus, the TIM is a device that systematically exposes each appropriate functional unit and/or component of a hardware to all maintenance functional verbs. If properly executed, it identifies all the maintenance tasks which that hardware can demand of its maintenance technicians, and it also limits the scope of each of these hardware specific tasks. As the result of the hardware maintenance concept, the TIM or TIMs will identify a different mix of maintenance tasks for each level of maintenance (organizational, intermediate, and depot). Although all three levels of maintenance can be included on one TIM, for complex hardware it usually is advisable to develop a separate TIM for each level.

e. Once a task is identified, it should be submitted to several analyses to determine its behavioral content and the most effective means for ensuring its efficient accomplishment. For example, the means selected for ensuring the accomplishment of a task might be one of *the following: (a) selecting personnel* who can already perform the task, (b) providing a FPJPA for the task, (c) providing supervised practice on the task (task specific ISD), or (d) using an appropriate combination of these means.

3. The TI&A technology assumes the completeness of both FPJPA and task specific ISD. For example, for the development of FPJPAs, it is necessary to identify all the task steps or directions required to perform that task and to ascertain the necessary pictorial content for each direction. This requires that each direction contain all of the *cues* required by members of the target population to perform the task step.

4. The cost effective implementations of the FPJPA technology and/or task specific ISD technology will require the modification of *ground rules* for clustering of hardware for personnel assignment codes.

a. For a combined implementation of FPJPA/task specific ISD, the hardware in a cluster can be rather heterogeneous as to their vintages of design. The FPJPA technology can compensate for much of task differences across the cluster. The combined technology can be applied successfully to maintenance situations where large groups of people are required to work on a small number of major hardware systems. For example, a cluster conceivably could include all the avionics hardware, without regard to their vintages, for one type of aircraft such as the C-141, or for a small group of functionally related aircraft types such as the C-141, the C-5, and the C-130.

b. Such combined applications of FPJPA/task-specific ISD would permit a gradual modification of the personnel system for maintenance. Basically, an AFSC would be identified with a cluster of hardware. This would require a mechanism for identifying the hardware which should be placed in the new clusters.

5. Occupational analysis technology with its capability already in-place for gathering a large amount of job related information could become an ideal vehicle for obtaining necessary information for the reclustering of hardware into more effective assignment codes. Effective reclustering of hardware will require a large amount of hardware specific human factors data for many hardware. If the occupational analysis technology is to be effective for such an enterprise, the technology would have to be modified to obtain maintenance job information on a hardware specific basis.

6. But without regard to this important reclustering requirement, an analysis of the current occupational analysis technology in the light of the TI&A technology indicates that several aspects of the occupational analysis technology prevent it from producing a realistic portrayal of the task content of most maintenance jobs.

a. Current occupational analysis surveys are designed to gather data concerning the frequency and difficulty of performance of each task/duty indicated and current analytic procedures manipulate the resulting data as if each task/duty statement represents a discrete and independent portion of the job or jobs of an AFSC. However, many of the job portions represented are not discrete and independent.

b. A typical task/duty statement now used for maintenance surveys contains a functional action verb coupled with a predicate object representing a *set* of several hardware found in the AFSC under consideration. Although having the same or similar operational function, the hardware items in many of these sets are extremely heterogeneous in terms of vintages of design. As a result of such heterogeneous hardware, a task/duty statement often represents a *set* of heterogeneous tasks, each hardware specific task in the set being quite different in its content and its human requirements.

c. Although many task/duty statements now used in surveys for maintenance jobs represent sets of extremely heterogeneous tasks, the maintainers accomplishes the survey based on their own limited frame of reference with regard to such a set. For many first-term maintainers, this frame of reference is limited to one specific hardware. Thus, such a task/duty statement has a different meaning for maintainers of varying hardware experience completing the survey form.

d. Because of the interaction and overlaps among hardware specific tasks, even the hardware specific task statements generated by a TIM cannot be treated as discrete and independent, (see Figure 1). This limitation also applies to statements representing sets of tasks. For example, a checkout activity can be a task in its own right but it can also be an element of a troubleshooting or an alignment task. Further, an alignment activity can be a task in its own right or an element of a troubleshooting task.

e. Since many of task/duty statements found in current occupational analysis surveys for maintenance job specialties do not represent discrete and independent portions of job activity, each frequency or difficulty datum gathered for each task/duty statement in a survey is not discrete and independent. Consequently, the current data manipulation procedures which assume discreteness are inappropriate for such data.

f. Because the current occupational analysis technology makes insufficient provisions for these several significant factors, its application to many maintenance AFSCs results in oversimplified and distorted pictures of their task content. More sensitive procedures should be used to gather, analyze, and display job data.

7. Figure 2 of this report presents a proposed format expanding the capability of the occupational analysis technology to obtain important hardware specific interface information concerning maintenance. It is envisioned that each maintainer will complete such a form for each hardware maintained. The order in which these forms are completed would reflect the relative amount of interaction that the maintainer has had with each hardware. This procedure should not require an extensive expansion in size when compared to current survey forms. As indicated previously, any first enlistment maintainers work on only a few of the hardware items assigned to an AFSC, many times on only one. In most cases, the number of hardware supervised by 7-level technicians should not be excessive, since any one maintenance supervisor seldom has more than five or six hardware items. The use of such a format has several important characteristics and advantages.

a. Although each job activity statement generated by this survey usually will not represent a specific and discrete hardware maintenance task, such a statement always represents a *set* of tasks with a common function which is specific as to its hardware and as to its level of maintenance (organizational or intermediate). The resulting job activity statements will be compatible with the task statements generated by the TIM (from the TI&A technology) for the same hardware. (The functions or functional action verbs are from the standard list of functions now used in TIMs as well as in modern maintenance instructions. So the content of each survey *set* can be identified on the TIM for the same hardware, if and when a TIM is available. This feature is a necessary change for making the occupational analysis technology compatible with both the FPJPA and task specific technologies.)

b. The format also provides for identifying the relationship the maintainer has had with each set of maintenance tasks such as "received hands-on training on activity," "assist in performance of activity," and "train others on performance of activity."

c. Since the data generated by the completion of Figure 2 survey form are hardware oriented rather than AFSC oriented, such data can be gathered against important frames of references other than AFSCs, such as by a major weapon system, by groups of weapon systems, by major command, or by maintenance units. Appropriate analyses of data gathered on these bases will identify important patterns of technician/job/hardware relationships for reclustering of hardware for improved maintenance specialty codes, as well as for cost-effective applications of task specific ISD and FPJPA technologies.

d. The proposed format retains the feature of current occupational analysis surveys for indicating an adjective-type estimate of time devoted to each indicated job activity.

8. There should be an interaction between the technology for TI&A and the proposed modification of the technology for occupational analysis indicated. Occupational analysis can gather a large amount of hardware specific human factors information concerning many hardware, but, for each hardware it identifies sets of maintenance tasks rather than specific tasks. The TI&A technology normally is applied to only one hardware item at a time, and its TIM identifies all individual maintenance tasks for that hardware. Thus, TIMs can be used to identify all of the tasks in any hardware specific set of tasks identified by the proposed occupational analysis survey form. Further, TI&A procedures together with their resulting products possess the capabilities for prescribing the detailed content of each task for FPJPA and/or task specific ISD. These are capabilities which even the expanded occupational analysis technology alone will not have.

9. An appropriate prime role for occupational analysis technology would be to gather hardware specific data across hardware on several bases (such as by a major weapon system, by groups of weapon systems, by major command, by maintenance units as well as by AFSC) and to appropriately analyze such data. Such analyses would identify patterns of personnel/job/hardware relationships for reclustering of hardware and/or personnel for cost effective applications of task specific ISD and/or FPJPA technologies. Once such a cluster is identified, the TI&A technology would be applied to all hardware in the cluster to identify all of the maintenance tasks in the cluster and to determine the detailed content of the task specific ISD and/or FPJPA required for cost-effective maintenance. Such reclustering coupled with the use of FPJPAs and task specific ISD, also, would result in better personnel assignment practices and more cost-effective utilization of Air Force manpower. All of these improvements would be further reflected in substantial reductions in the life cycle costs of ownership of hardware systems.

10. Table 1 provides descriptive summaries of several matrix-type displays. Such displays would provide personnel information concerning hardware specific sets of tasks. These matrices would identify patterns of hardware/personnel combinations for the reclustering of hardware for cost effective applications of FPJPA and/or task specific ISD technologies. Matrices of this type also would provide valuable bases for restructuring existing AFSCs without regard to these improved technologies. Table 2 provides descriptive summaries of similar matrix displays for indicating frequency and difficulty data for the same hardware specific sets of tasks.

11. Each Air Force Systems Command (AFSC) or Air Force Logistics Command (AFLC) hardware manager can provide valuable information concerning specific hardware which should support and supplement the hardware specific data gathered by the proposed occupational analysis survey procedures. The manager's potental contribution would include data such as the total number of hardware units currently in the Air Force inventory, the number of additional units the Air Force expects to acquire, and the locations or proposed locations of each of these units, as well as data concerning the number of line replaceable units (LRUs) and shop replaceable units (SRUs) in the hardware. The numbers of LRUs and SRUs are important data for assessing the magnitude of troubleshooting. The inclusion of this source in the occupational analysis technology would further improve this technology for developing cost-effective maintenance, personnel and training systems.

12. The main thrust of this report concerns refining and coordinating technologies involved in occupational analysis and TI&A (as associated with FPJPAs and ISD for task specific training). Special attention was directed to important differences among similarily named maintenance tasks. There are some threads of commonality among maintenance tasks. Examples are as the use of common test equipment and hand tools, which can affect the performance of many maintenance tasks across many hardware. These threads require identification and strengthening. Some of the current problems concerning such common task elements are discussed. Table 3 provides suggested formats for gathering information concerning the use of authorized common and special test equipment and hand tools.

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